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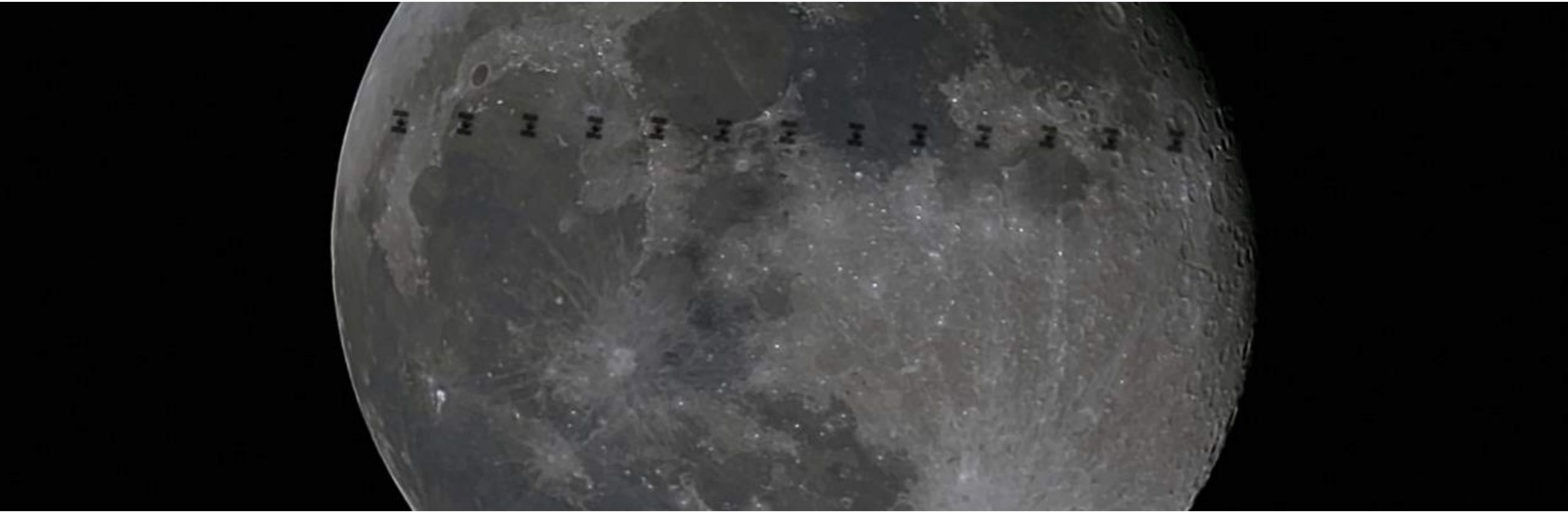

MAPP FINAL PRESENTATION

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Final Presentation

MAPP
INDEX

MAPP
Introduction

- **MAPP:** **M**iniaturized **A**ntennas for **P**lanetary mission **P**robes

- **Background:**

  June 2003: Beagle 2 was launched in the Mars Express Mission. It was transported and successfully released on December 19th 2003 by the orbiter. No signal was received. One of the recommendations from the Commission of Inquiry concluded that future planetary entry missions

  The Exomars 2016: first mission that included an Entry, Descent & Landing Demonstrator (EDL-demo) module and an Orbiter module to provide data relay functions. UHF-Band system for proximity link. The communication link using conventional omnidirectional showed some limitations. Wrap-around conformal antennas are considered a very good alternative.

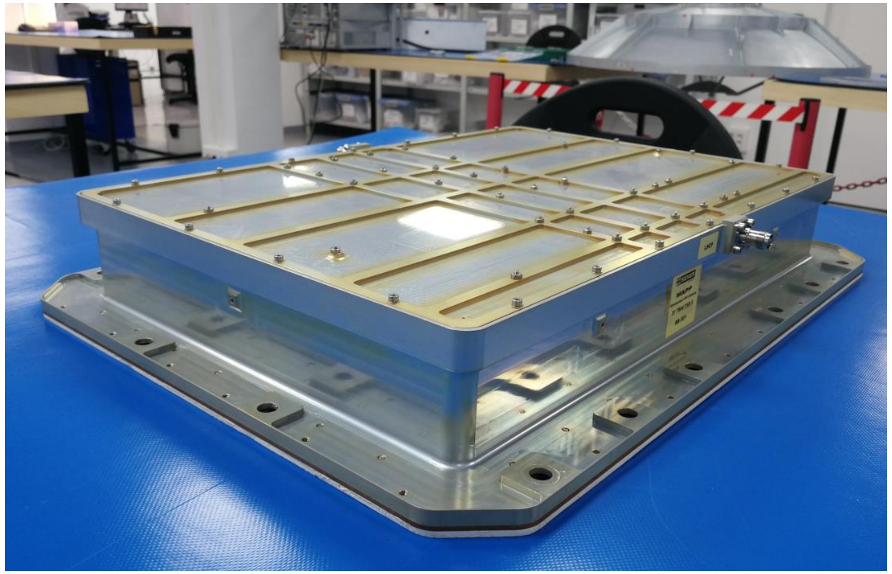
  Phoenix lander UHF wraparound conformal antennas have been successfully used on the during EDL.

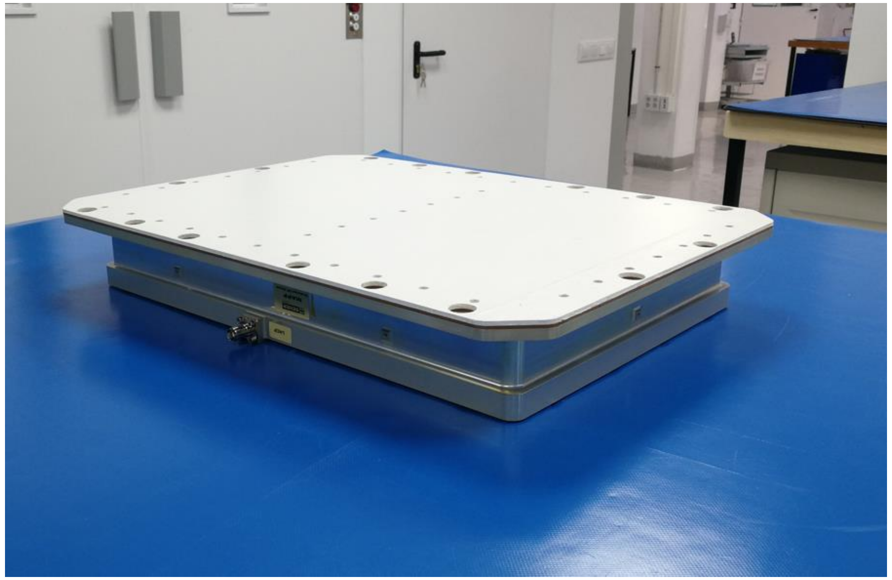
- **Objective**: The objective of the activity was to develop a miniaturized conformal antenna for Entry, Descent and Landing phases of planetary mission probes, compliant with the technical requirements.

- **Benefits**: General requirements and design trade-offs have been identified for these type of mission and antennas. Early design has demonstrated some capabilities (miniaturization of radiating elements, power handling, double polarization, etc.)

MAPP
Outline

Task 1: Antenna Requirements Review → Task 2: Preliminary Design and Analysis → Task 3: Critical Bread-boarding Activities → Task 4: Detailed Design and Analysis → Task 5: Manufacturing and Testing → Task 6: Conclusions and Development plan





MAPP
Reference Documentation

AD#	Title	SENER Code	Client Code
[AD 01]	ESA Contract No. 4000133224/20/NL/AS "Miniaturised Antennas for Planetary Mission Probes"		ESA Contract No. 4000133224/20/NL/AS
[AD 02]	Statement of Work ESA Express Procurement Plus - EXPRO+ Miniaturised Antennas for Planetary Mission Probes		AO10259-ws00pe_SOW
[AD 03]	MAPP detailed requirements document	MAPP-AN-0032-SEN	
[AD 04]	Breadboard test report for MAPP antenna	MAPP-TR-0033-SEN	
[AD 05]	Electrical & worst-case analysis for MAPP antenna	MAPP-AN-0035-SEN	
[AD 06]	MAPP EM Antenna test report	MAPP-TR-0014-SEN	
[AD 07]	Test plan for MAPP antenna	MAPP-PL-0039-SEN	
[AD 08]	MAPP antenna development plan	MAPP-PL-0014-SEN	
[AD 09]	MAPP Breadboard description and analysis	MAPP-AN-0031-SEN	
[AD 10]	MAPP Breadboard test plan	MAPP-PL-0012-SEN	
[AD 11]	MAPP antenna thermal analysis	MAPP-AN-0005-SEN	
[AD 12]	MAPP antenna mechanical analysis	MAPP-AN-0004-SEN	

MAPP
Requirement analysis

- A detailed discussion and analysis at mission and system level was performed to define the requirements at several levels:

- Physical
- Structural
- Thermal
- Radiation
- Power
- EMC
- Verification
- RF

Requirement	Value
Frequency	UHF 400 MHz
Bandwidth	390 MHz to 413 MHz
Gain	Max. pointing between |30°| < θ < |70°|: > 3 dBi FOV Gain -> -3 dB
Polarisation	Dual Circular
Crosspolar Level	-15 dB FoV
FoV	Template defined between |10°| and |95°|
VSWR	1.4:1
Power Handling	55 W
Multipaction Analysis Margin	12 dB
Corona Analysis Margin	12dB

MAPP

Initial trade-offs and preliminary design

1. Multi stacked PIFA antenna, **concept A**

Double polarization

Better performance

High complexity (feeding network)

Narrower bandwidth

2: Spiral antenna concept B

Larger bandwidth

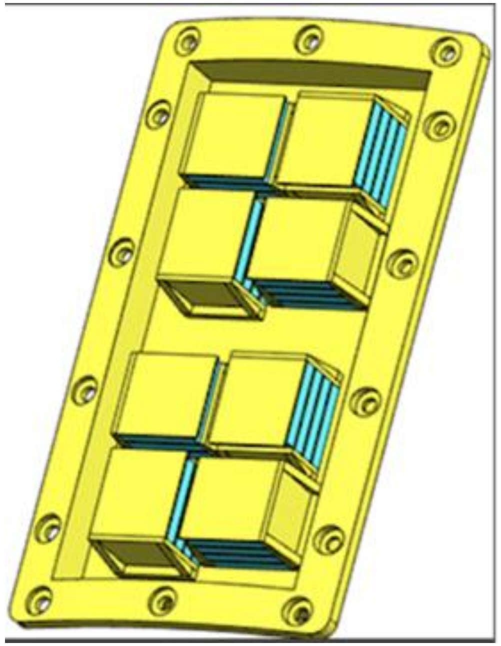
Single polarization

Higher complexity (feeding network + balum)

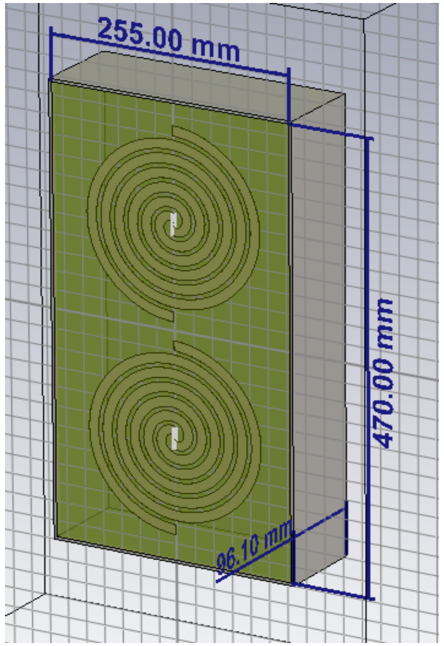
Higher mass

Worse performance

A



B



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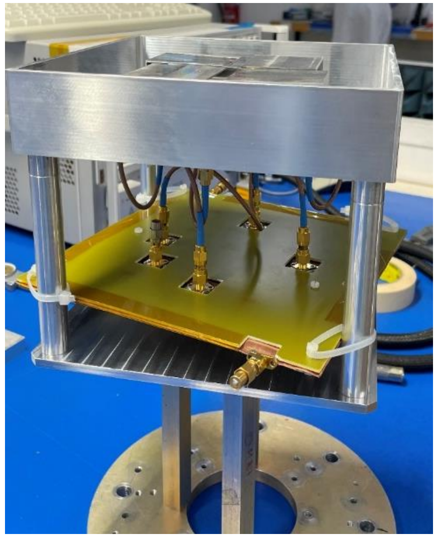
Breadboard preliminary design and test

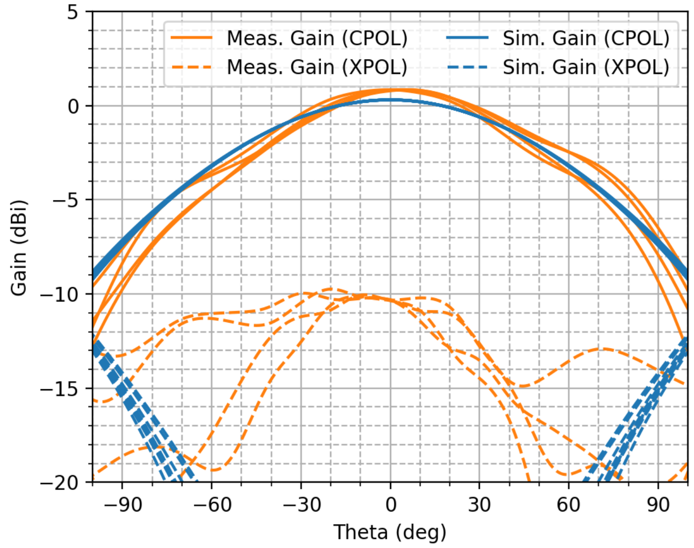
Test results expected by analysis

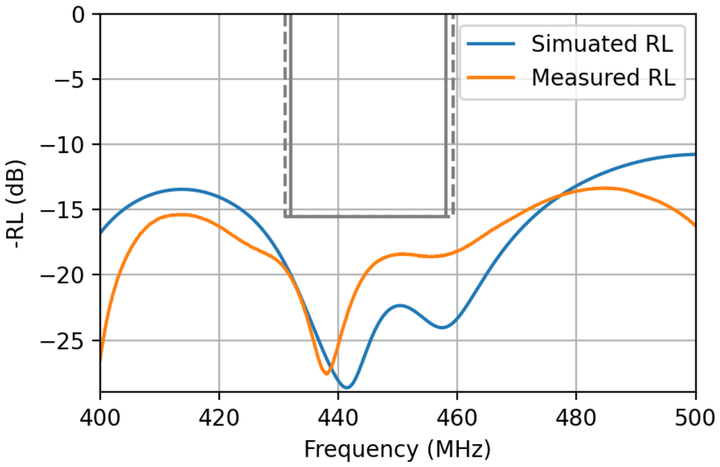
Crosspolar (axial ratio) axial ratio and a slight asymmetry of the radiation pattern.

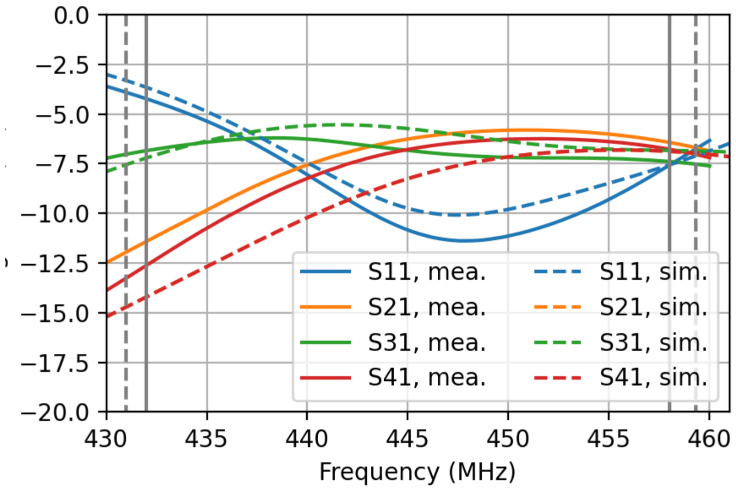
- Compatible with a defective connection

The BB measurements confirmed the suitability of the antenna simulations





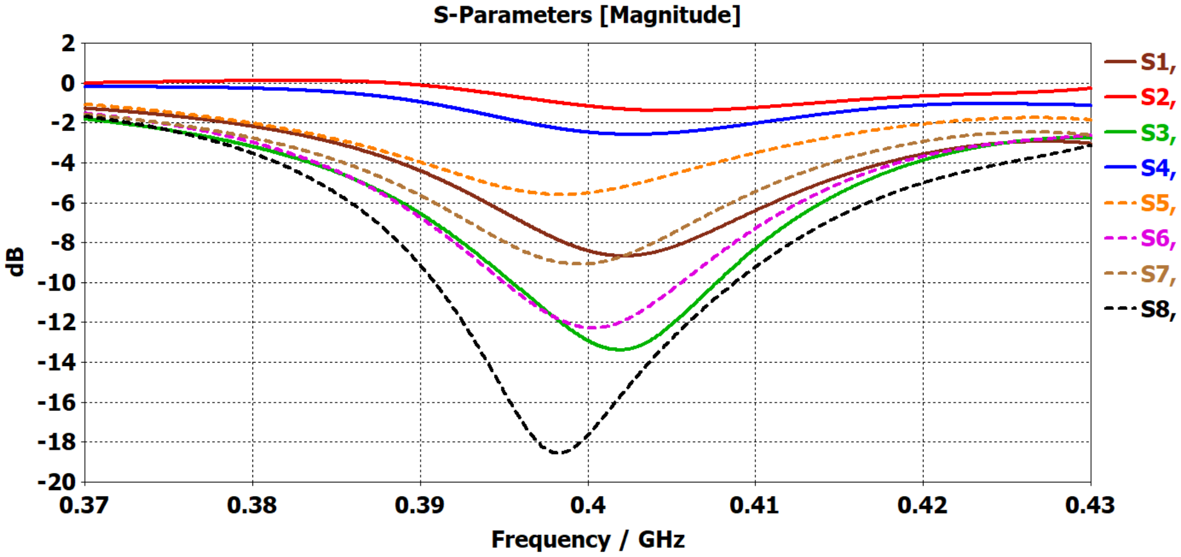


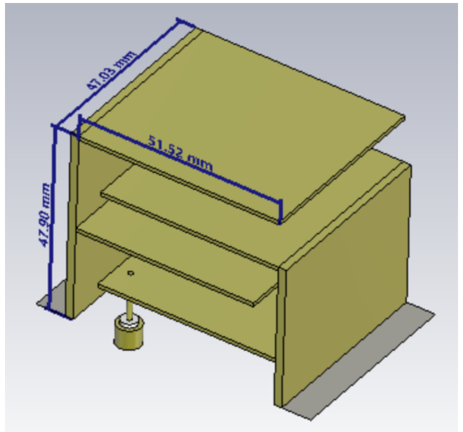


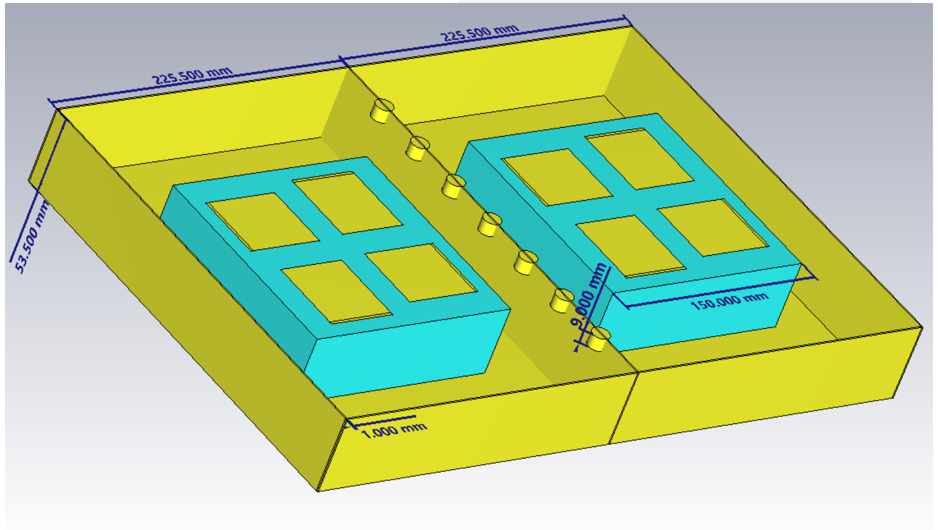
MAPP

Detailed RF Analysis

1) Radiating element performance



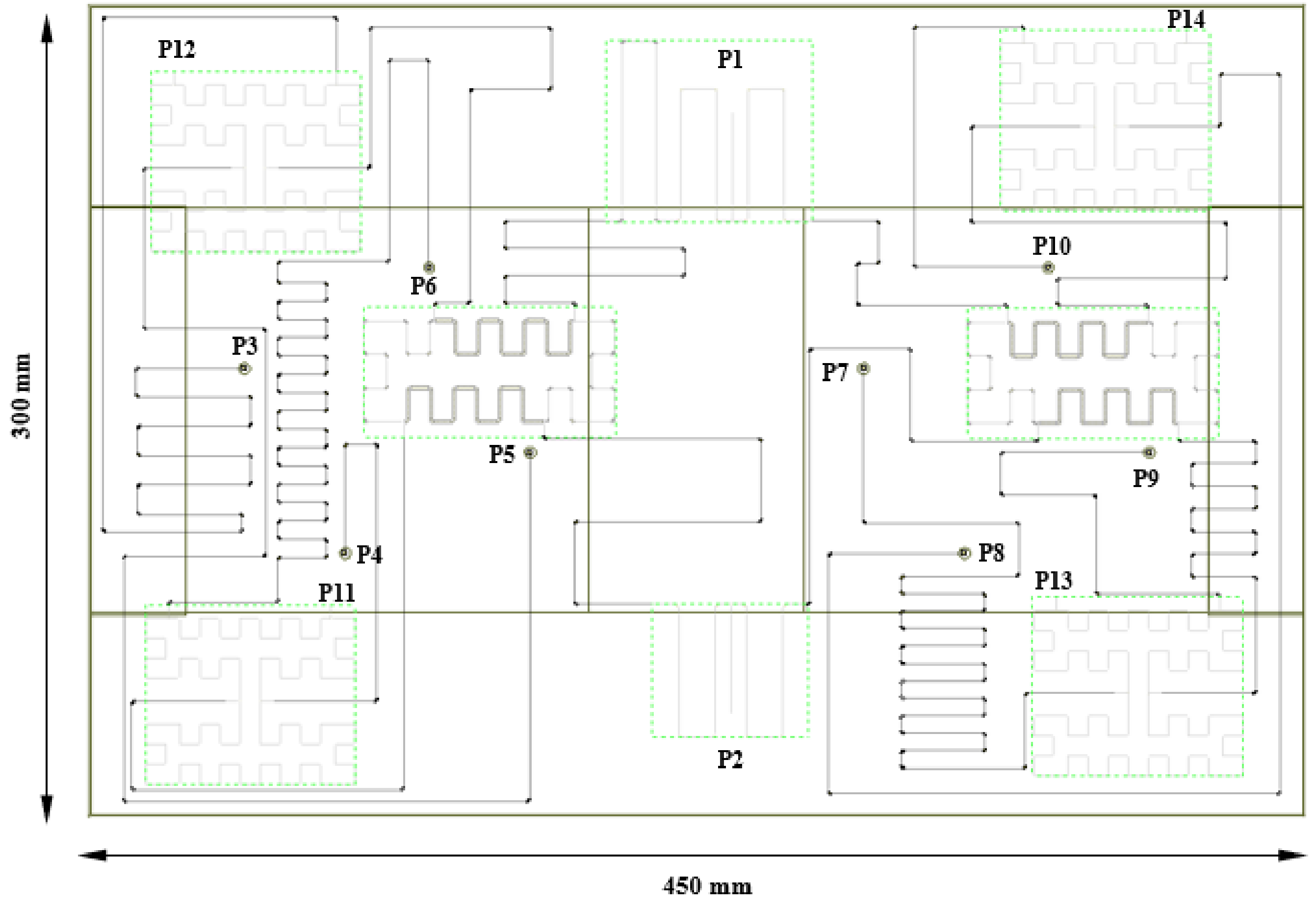




MAPP
Detailed RF Analysis

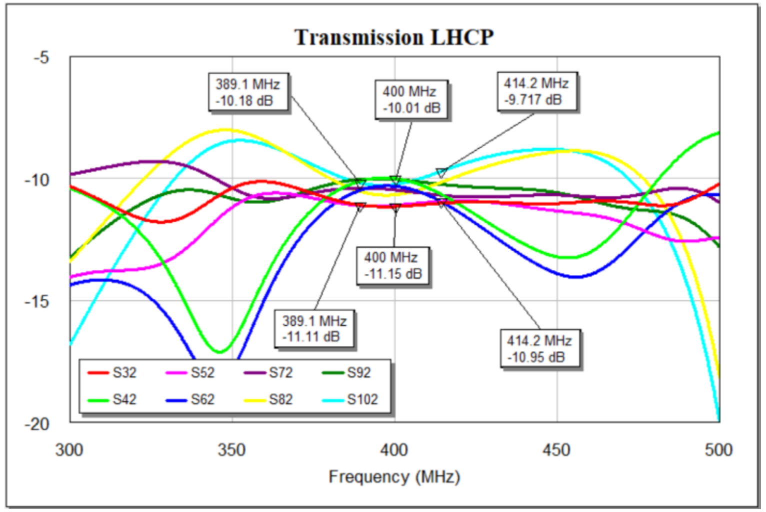
2) Feeding network

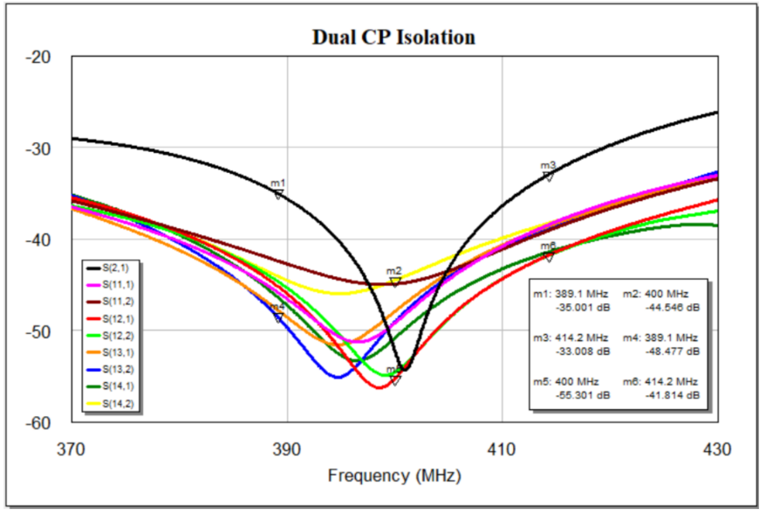
- Stripline technology (Nelco NX9255)
- Single layer
- Dual polarization



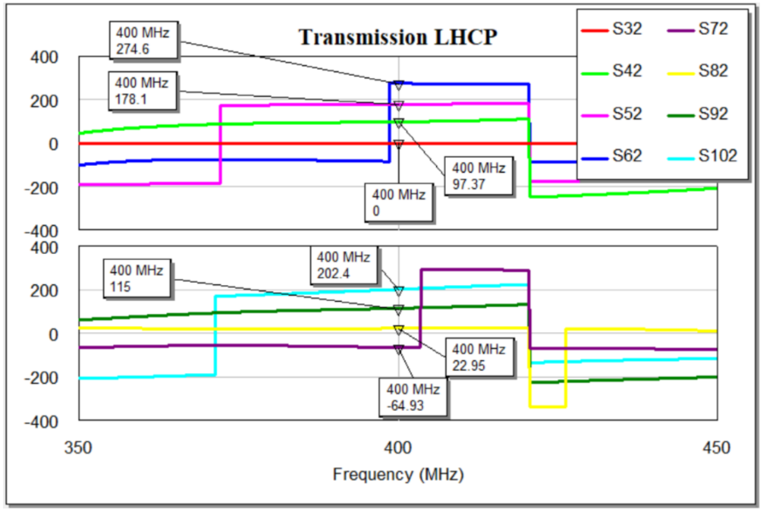
MAPP

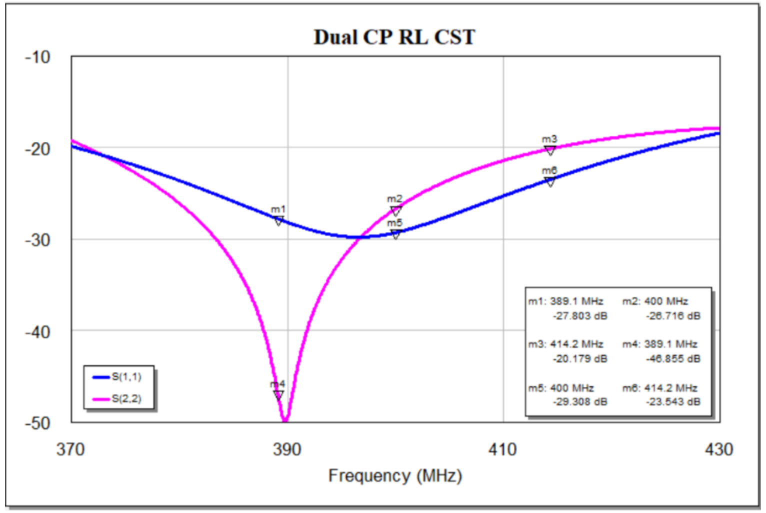
Detailed RF Analysis





Feeding network performance

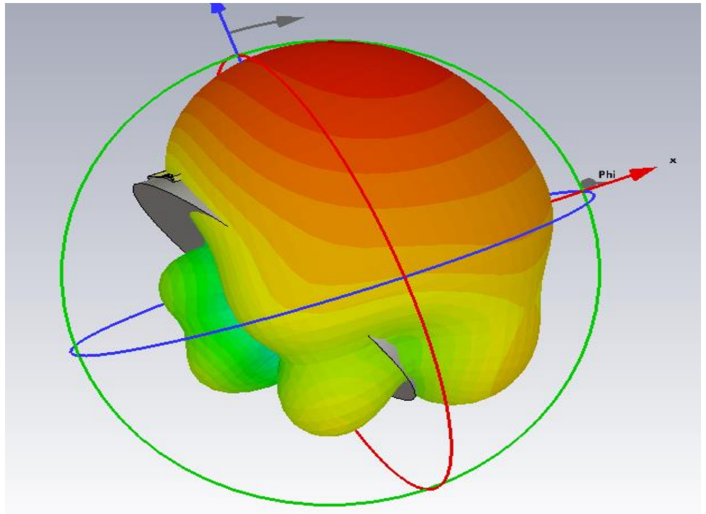


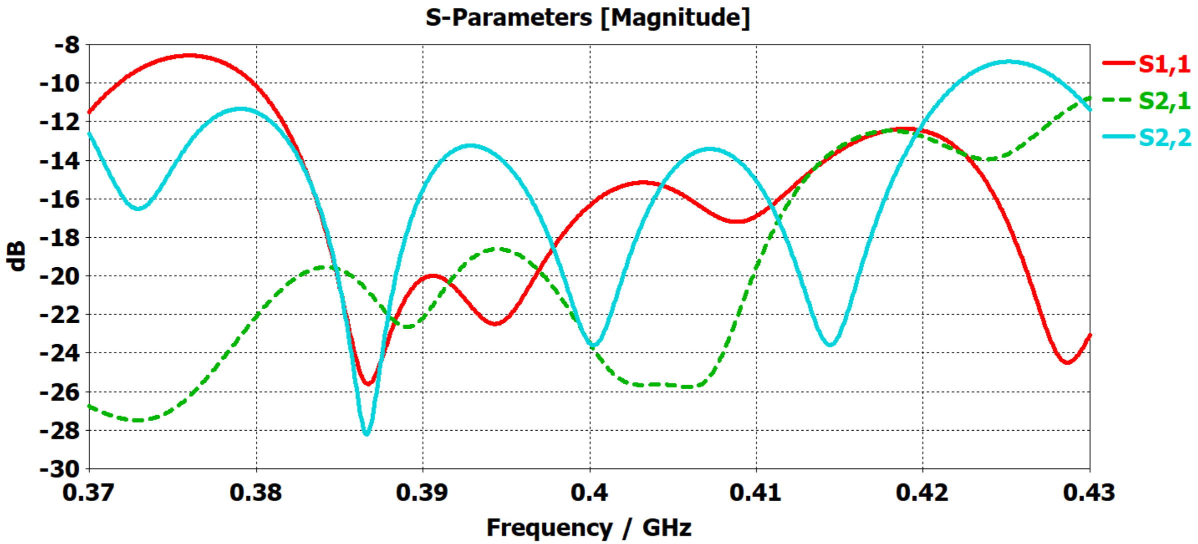


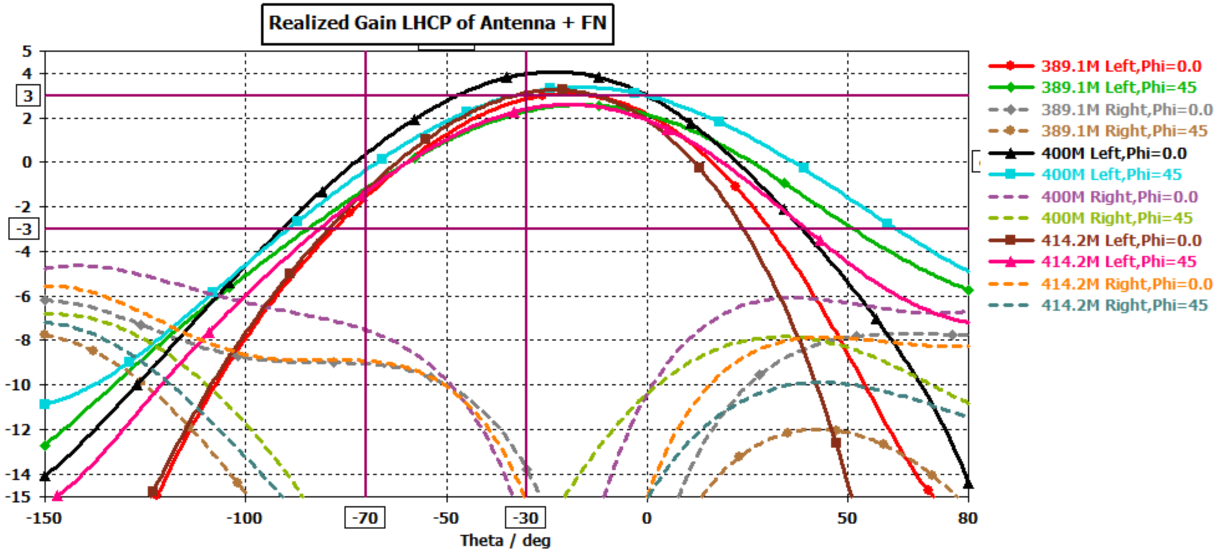
MAPP

Detailed RF Analysis

3) Antenna assembly performance



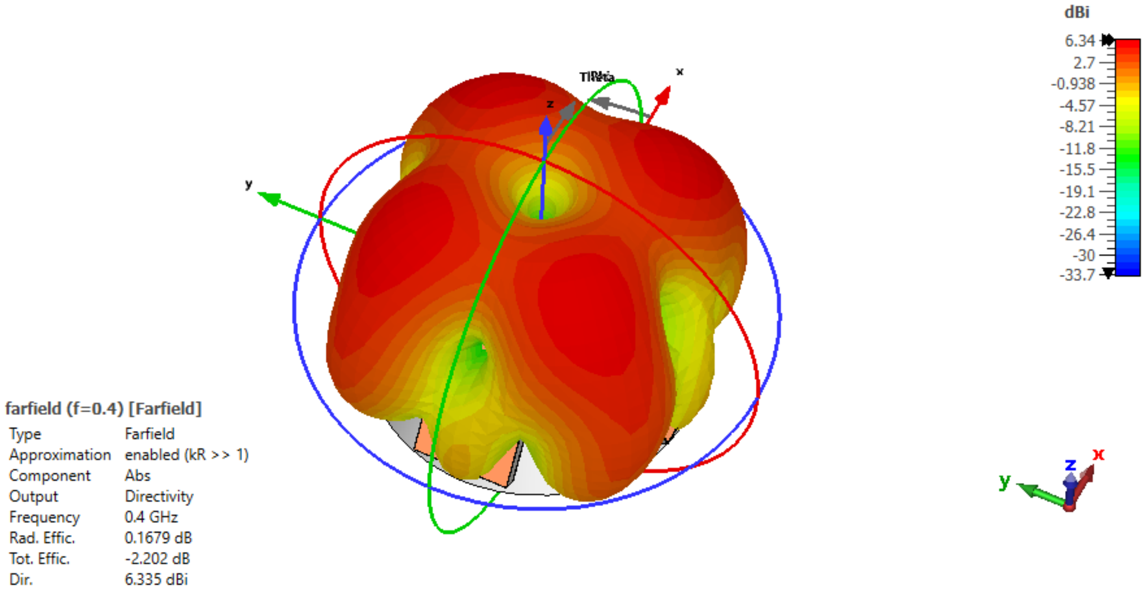


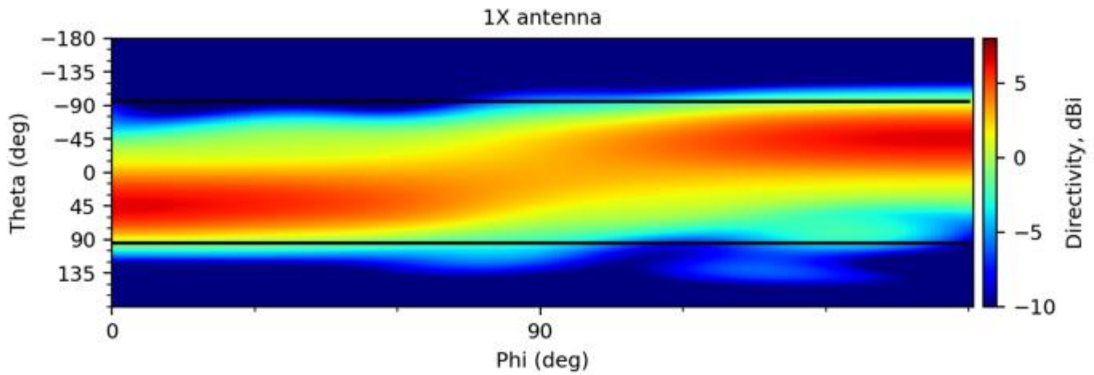


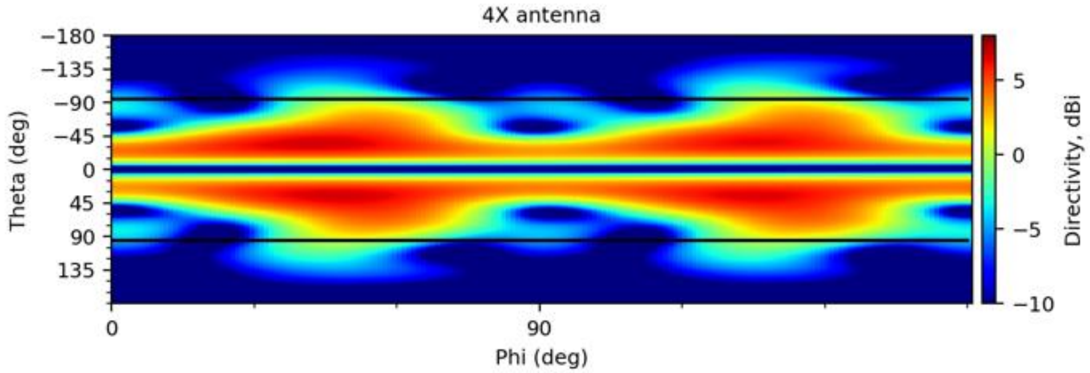
MAPP
Detailed RF Analysis

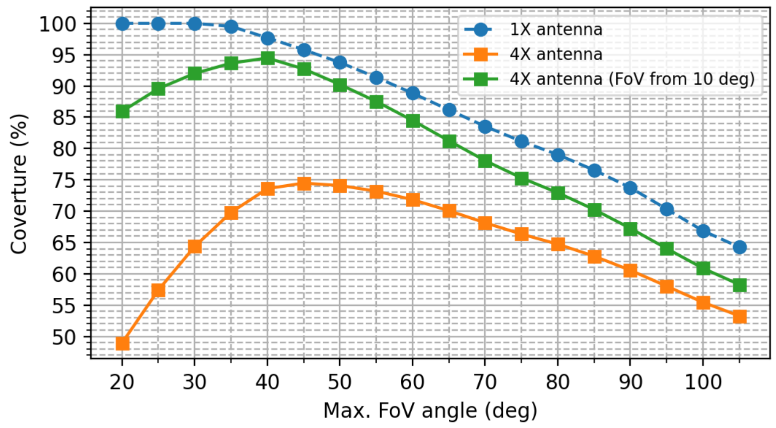
4) Conformal array performance

A single antenna might outperform the conformal array in certain circumstances









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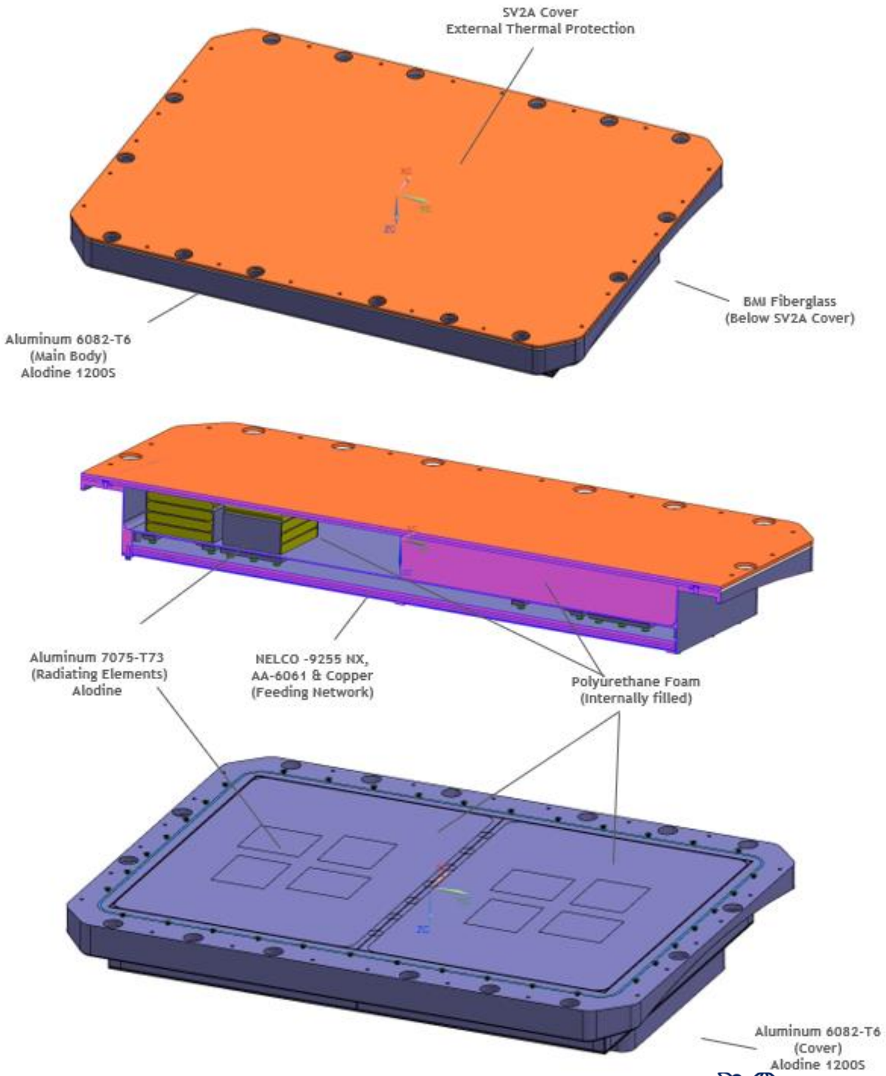
Detailed Mechanical & Thermal Analysis

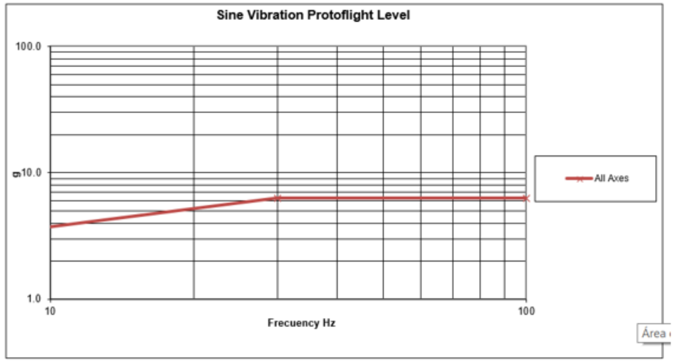
The unit has been designed to be compliant with the following environmental requirements:

- Modal Analysis
- Quasi-static loads
- Sinusoidal vibration
- Random Vibration
- Shock level
- Depressurization
- Thermal loads
- Thermo-elastic loads



MAPP

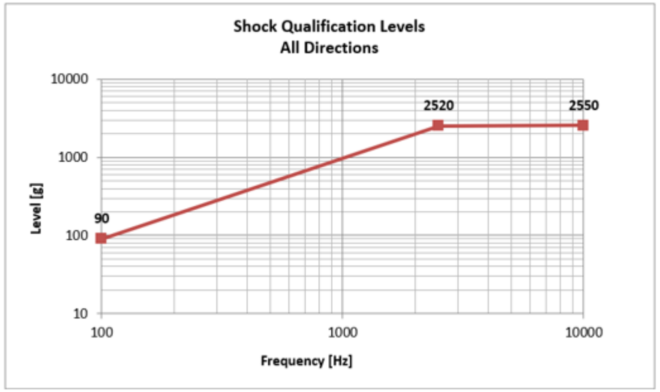
Detailed Mechanical & Thermal Analysis

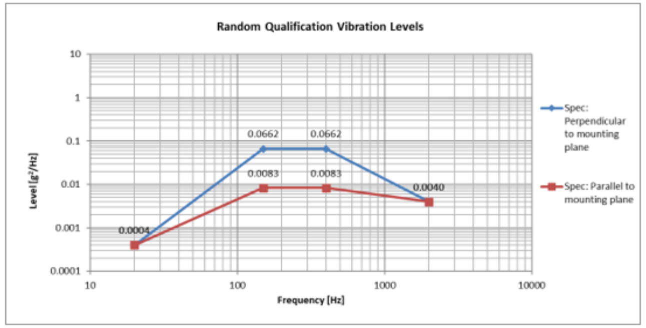


Sine Proto-Flight Vibration Levels		
Axis	Frequency [Hz]	Level [0-Pk]
ALL	5 30 100	2.7 g 6.3 g 6.3 g

Shock Qualification Levels		
Axis	Frequency (Hz)	Level [g]
All	100	90 g
	2500	2520 g
	10000	2550 g

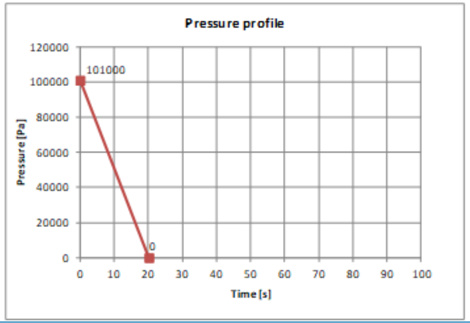
Table 4-7: Shock Qualification Levels





Random Proto-Flight Vibration Levels Parallel to Mounting Plane			
Axis	Frequency [Hz]	Level [g^2/Hz]	Slope [dB/Oct]
X, Y	20 80 600 2000	0.004 0.1 0.1	-8
Overall Level: 9.3 g RMS			

Random Proto-Flight Vibration Levels Perpendicular to Mounting Plane			
Axis	Frequency [Hz]	Level [g^2/Hz]	Slope [dB/Oct]
Z	20 80 600 2000	0.004 0.2898 0.2898 0.0124	
Overall Level: 15.8 g RMS			
Duration: 1 min/axis			



Time [s]	Pressure [Pa]	Rate [Pa/s]
0	101000	
21	0	-4500

MAPP

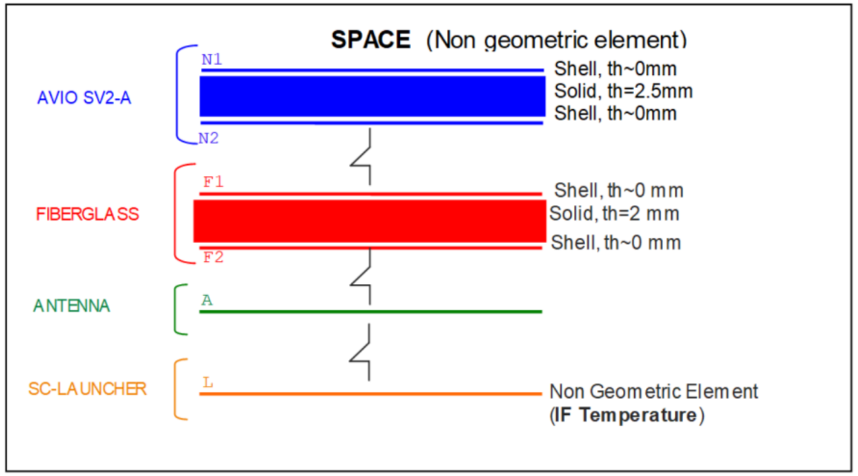
Detailed Mechanical & Thermal Analysis

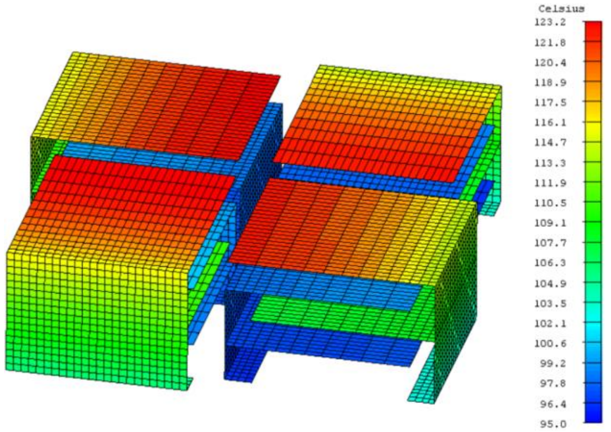
OPERATING HOT CASE				
Components	Materials	Calculated Max T [°C]	Predicted [°C] (+20°C included)	Material Qual. T Range [°C]
Radiating elements, Main Body, Cover	Aluminium 7075-T73 / 6082-T6 (alodine)	123.2	143.2	-170 / +204 (SENER Aeroespacial Qualification Campaign)
Polyurethane Foams	LAST-A-FOAM RF-2203	141.3	161.3	Cryogenic up to +171 (1) (Manufacturer: General Plastics)
Feeding Network	NELCO-9255 NX	124.7	144.7	Cryogenic up to +260°C (2)
BMI Cover	BMI Fiberglass	149.0	169.0	Cryogenic up to +550 (Manufacturer)
Thermal Protection SV2A Cover	AVIO SV2-A	150.0	170.0	Cryogenic up to +450 AVIO (3)
Connector	---	87.0	89.0	-220 / +165 See derating table (RD07) (4)

Table 6-7: Design vs. material qualification temperatures. OPERATING HOT CASE

NON-OPERATING COLD CASE				
Components	Materials	Calculated Min T [°C]	Predicted [°C] (-20°C included)	Material Qual. T Range [°C]
Radiating elements, Main Body, Cover	Aluminium 7075-T73 / 6082-T6 (alodine)	-87.4	-107.4	-170 / +204 (SENER Aeroespacial Qualification Campaign)
Polyurethane Foams	LAST-A-FOAM RF-2203	-122.6	-142.6	Cryogenic up to +171 (1) (Manufacturer: General Plastics)
Feeding Network	NELCO-9255 NX	-82.6	-102.6	Cryogenic up to +260°C (2)
BMI Cover	BMI Fiberglass	-136.9	-156.9	Cryogenic up to +550 (Manufacturer)
Thermal Protection SV2A Cover	AVIO SV2-A	-137.2	-157.2	Cryogenic up to +450 AVIO (3)
Connector	---	-82.7	-102.7	-220 / +165 See derating table (RD07) (4)

Table 6-8: Design vs. material qualification temperatures. NON-OPERATING COLD CASE



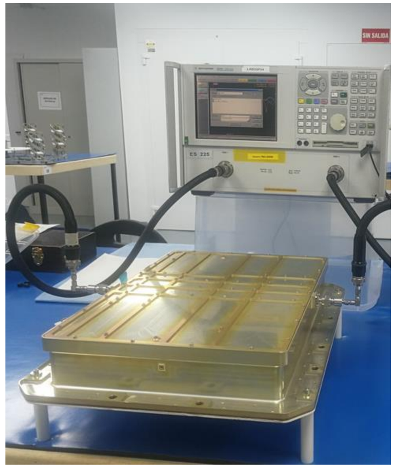


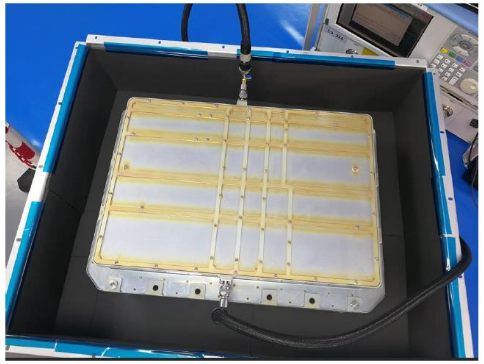
MAPP

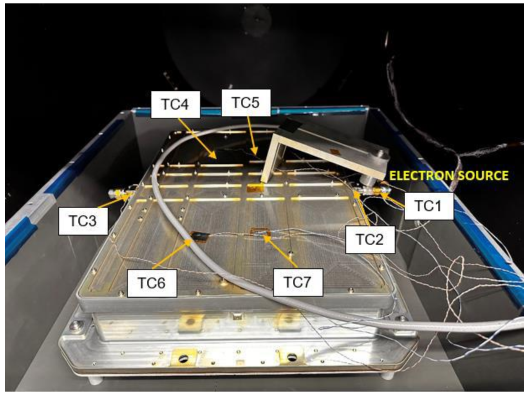
Summary of Test Results

- This antenna is an EM model: BB S/N 001. All the test has been performed in SENER facilities, following the applicable test procedures and test plan.

MAPP UHF Antenna Model: EM TEST MATRIX	1	2	3	4	5	6	7	8		
TEST	RETURN LOSS AND ISOLATION	RADIATION PATTERN	GAIN AND AXIAL RATIO	POLARISATION	DIM. VERIFICATION	MASS	VISUAL INSPECTION	CORONA TEST	OPERATING	NON-OPERATING
INITIAL INSPECTION					X		X			X
MASS PROPERTIES						X				X
INITIAL PERFORMANCE	X	X	X	X					X	
VIBRATION SURVEY										X
SINE VIBRATION										X
VIBRATION SURVEY										X
RANDOM VIBRATION										X
VIBRATION SURVEY										X
POST VIBRATION PERFORMANCE	X								X	
THERMAL TESTS (2 CYCLES)[1]	X								X	
POST THERMAL AMBIENT FUNCTIONAL	X								X	
CORONA TEST[2]								X	X	
FINAL PERFORMANCE	X	X	X	X					X	







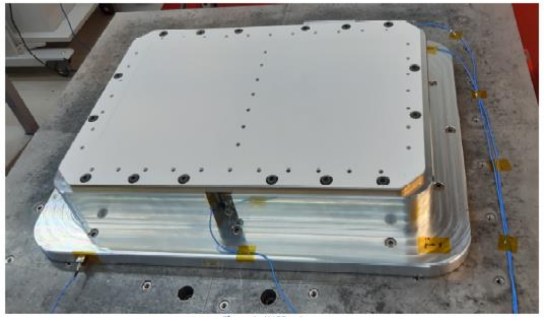
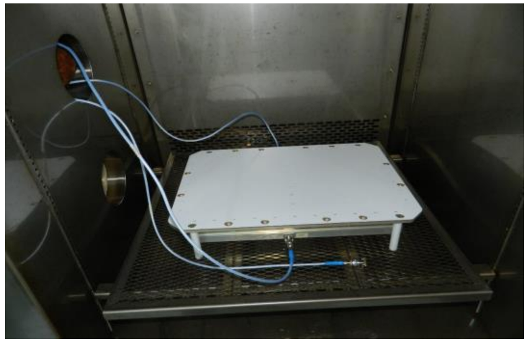
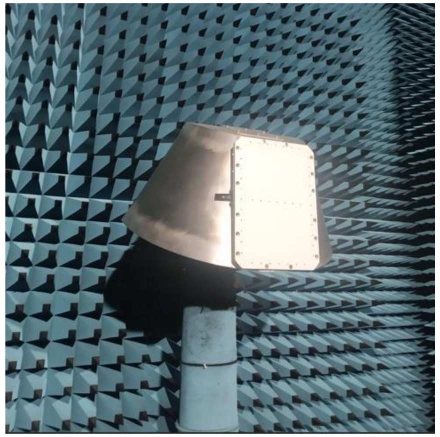


Figure 1: MAPP antenna





- Additional Thermal Test (2 additional cycles).
- Additional Corona step Test.

MAPP
Summary of Test Results

RF test

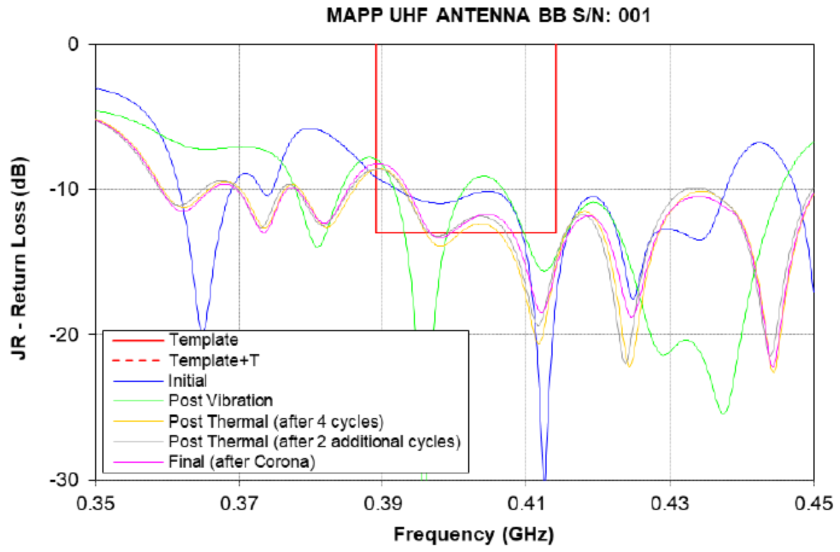


Figure 3-2: Return Loss JR Port BB S/N: 001. Electrical Measurements.

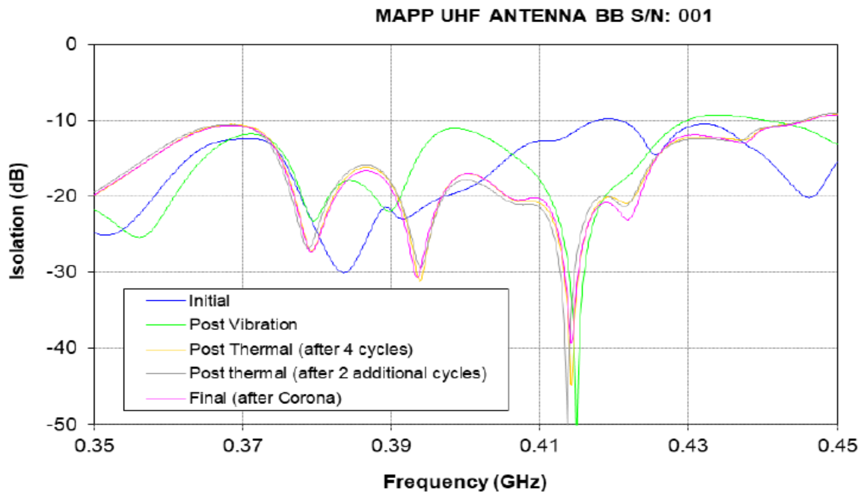


Figure 3-4: Isolation between ports BB S/N: 001. Electrical Measurements.

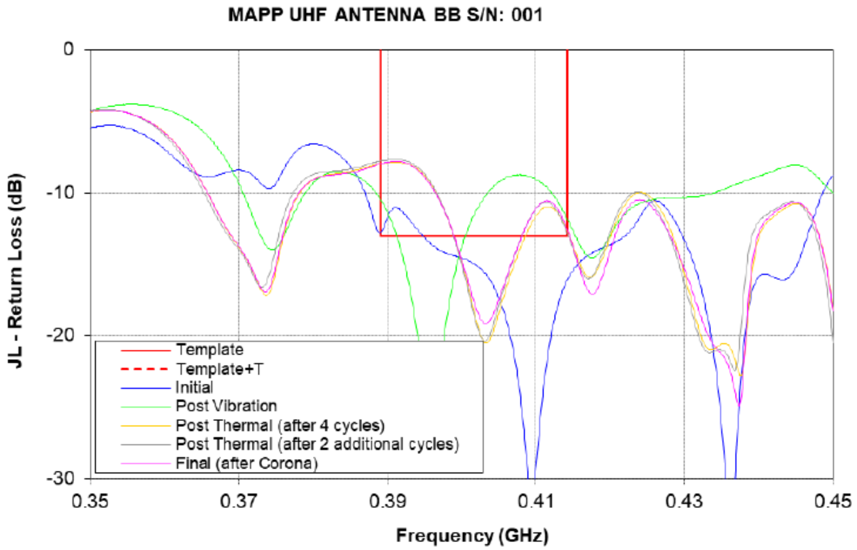


Figure 3-3: Return Loss JL Port BB S/N: 001. Electrical Measurements.

MAPP

Summary of Test Results

Radiation test. Final test

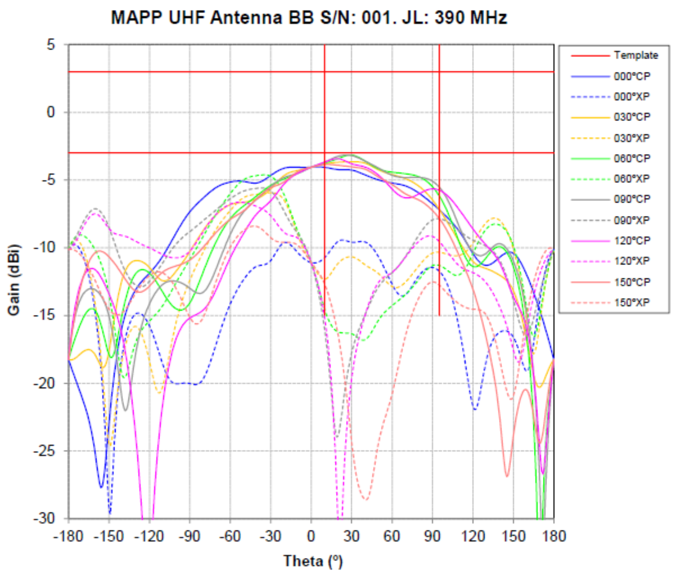


Figure 3-21.- Gain Pattern BB S/N: 001. JL Port. F1: 390 MHz. Final Functional

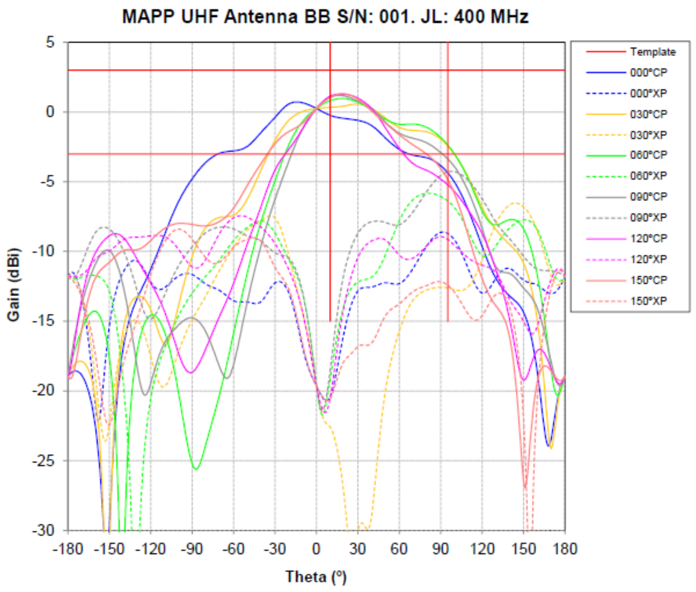


Figure 3-22.- Gain Pattern BB S/N: 001. JL Port. F2: 400 MHz. Final Functional

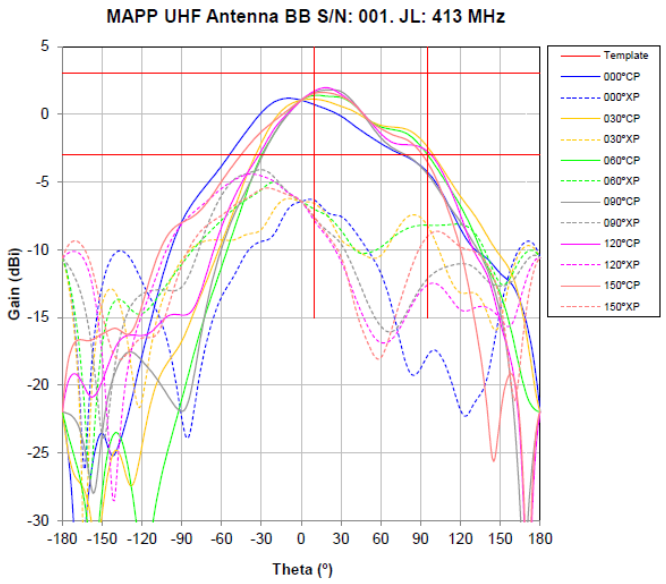


Figure 3-23.- Gain Pattern BB S/N: 001. JL Port. F3: 413 MHz. Final Functional

MAPP

Summary of Test Results

Radiation test. Final test

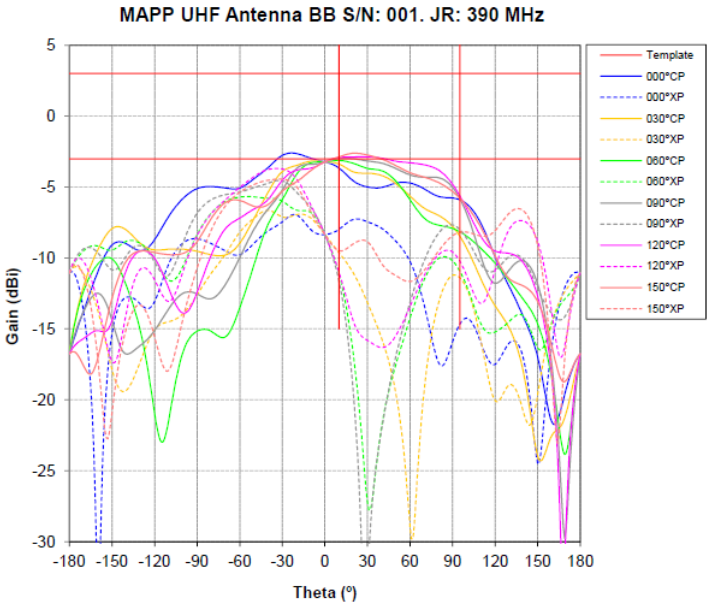


Figure 3-24.- Gain Pattern BB S/N: 001. JR Port. F1: 390 MHz. Final Functional

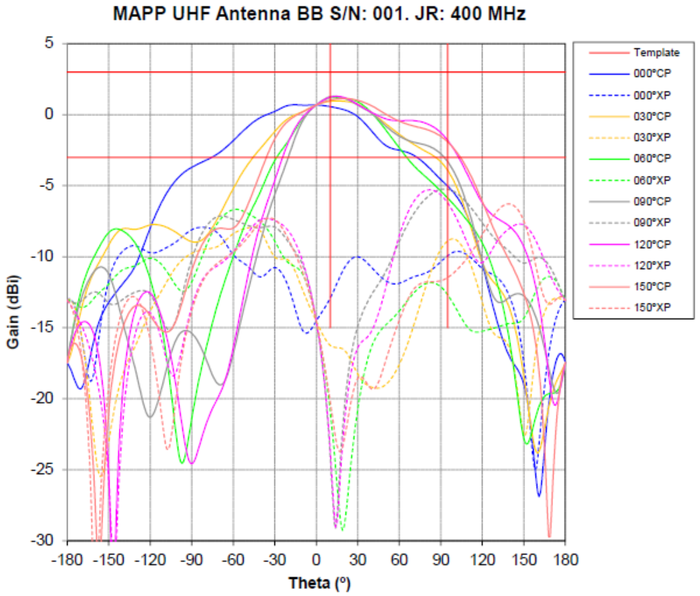


Figure 3-25.- Gain Pattern BB S/N: 001. JR Port. F2: 400 MHz. Final Functional

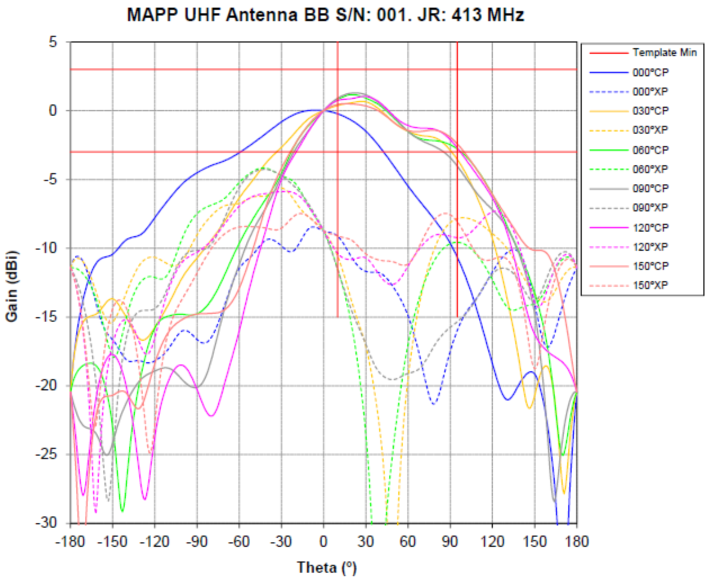


Figure 3-26.- Gain Pattern BB S/N: 001. JR Port. F3: 413 MHz. Final Functional

MAPP

Summary of Test Results

Radiation test. Final test

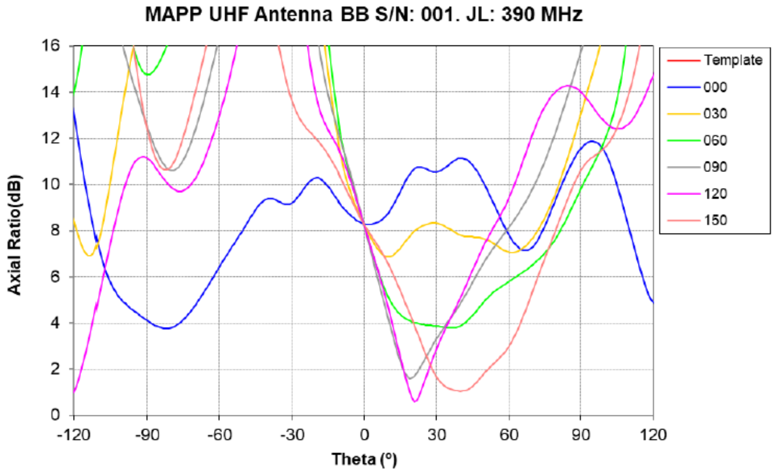


Figure 3-27.- Axial Ratio BB S/N: 001. JL Port. F1: 390 MHz. Final Functional

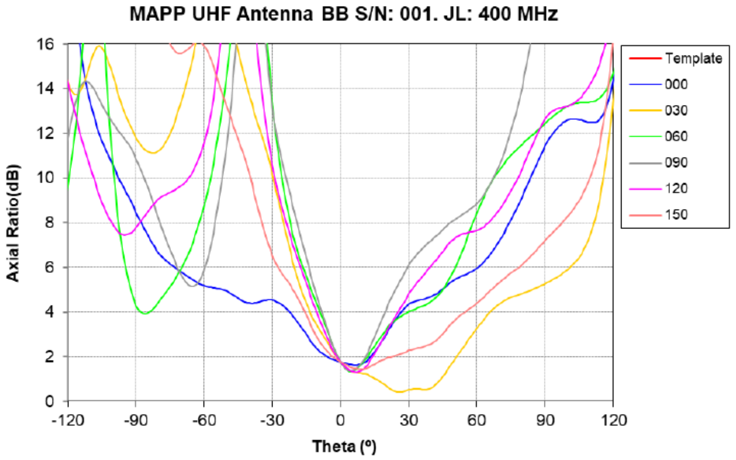


Figure 3-28.- Axial Ratio BB S/N: 001. JL Port. F2: 400 MHz. Final Functional

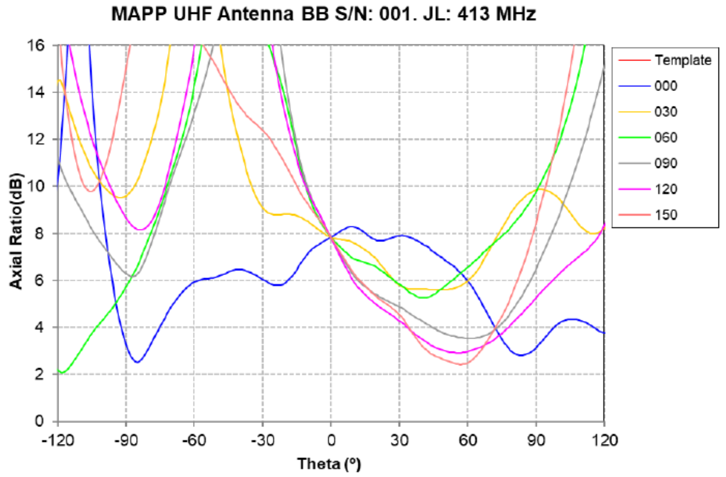


Figure 3-29.- Axial Ratio BB S/N: 001. JL Port. F3: 413 MHz. Final Functional

MAPP

Summary of Test Results

Radiation test. Final test

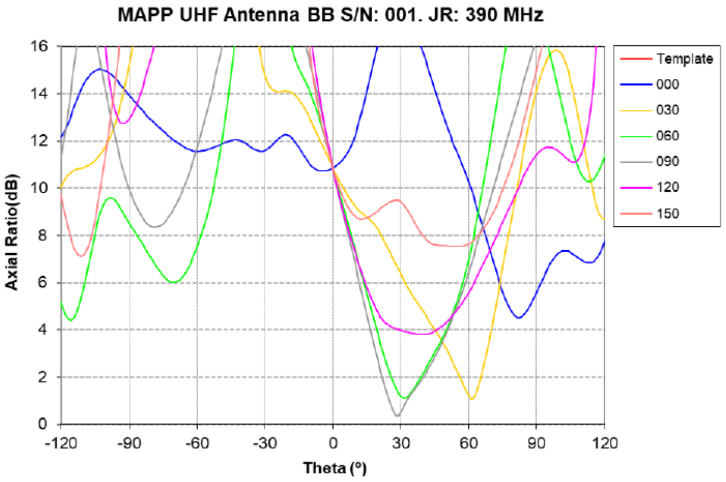


Figure 3-30.- Axial Ratio BB S/N: 001. JR Port. F1: 390 MHz. Final Functional

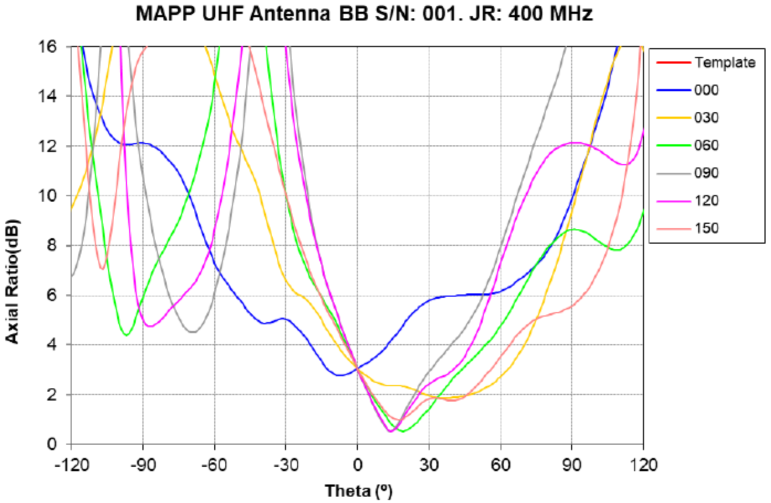


Figure 3-31.- Axial Ratio BB S/N: 001. JR Port. F2: 400 MHz. Final Functional

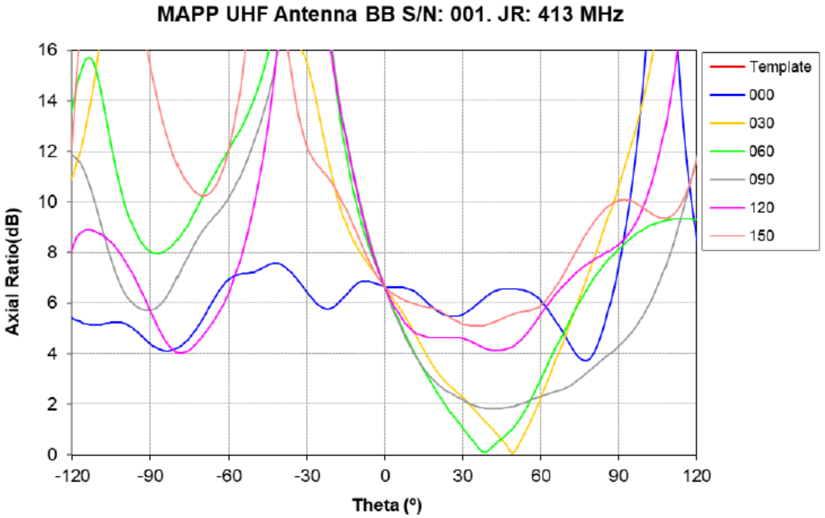


Figure 3-32.- Axial Ratio BB S/N: 001. JR Port. F3: 413 MHz. Final Functional

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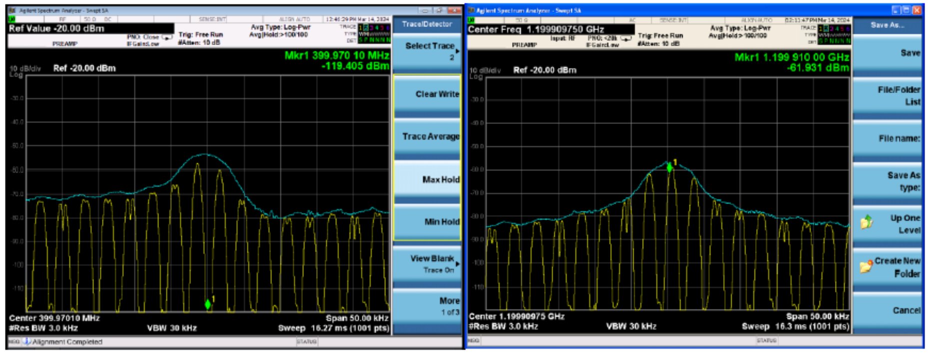
Summary of Test Results

Corona Test

- Antenna test up to 42 dBm Mean Power depressurization:



Antenna test with two depressurizations of average power of 43 dBm (in both we detected discharges with both methods):

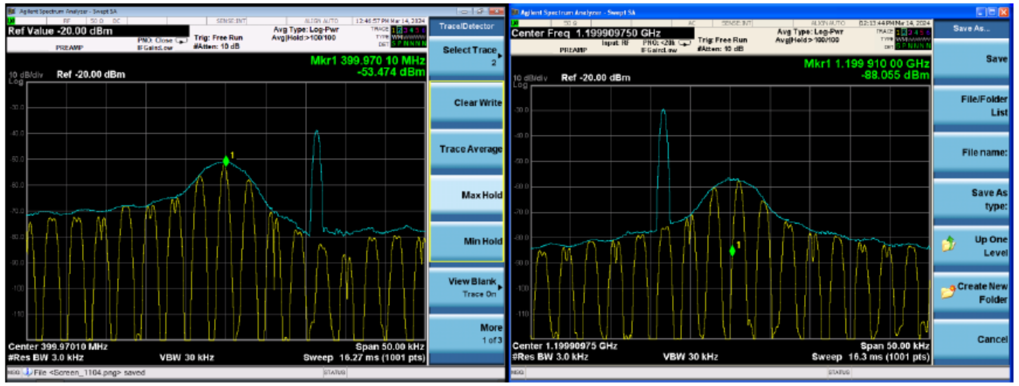


Figure 3-48: Nulling and 3rd harmonic . Corona discharge.

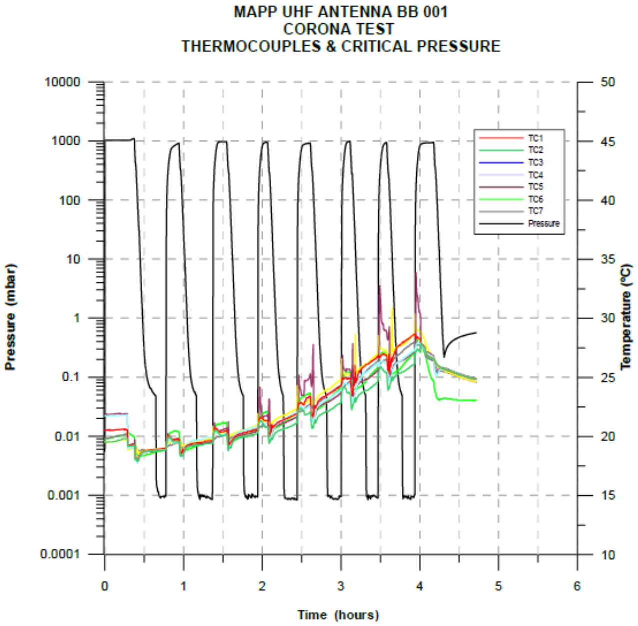


Figure 3-51: Pressure and Power Recording-Corona Test.

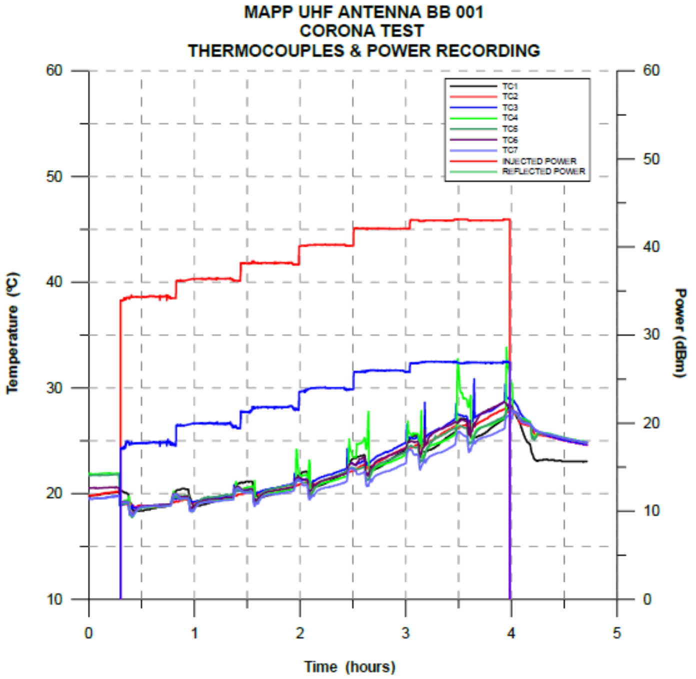


Figure 3-50: Thermocouples and Power Recording-Corona Test.

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Summary of Test Results

Statement of Compliance

PARAMETER	SPEC. VALUE	WORST VALUE			STAT. OF COMP.	REMARKS
		INITIAL	POST VIBRATION	FINAL		
Frequency Range	UHF 400 MHz	400 MHz			C	
Bandwidth	390 MHz to 413 MHz	390 MHz to 413 MHz			C	
Polarisation	Port JL : LHCP Port JR : RHCP	Port JL : LHCP Port JR : RHCP			C	
Gain	Max. Pointing between I30º I<θ< I70ºI > 3 dBi FoV Gain > -3 dBi	Max pointing NC I30º I<θ< I70ºI < 3 dBi FoV gain > -7.5 dBi (400 MHz, 413 MHZ) FoV gain > -8 dBi (390 MHz)	---------	Max pointing NC I30º I<θ< I70ºI < 3 dBi FoV gain > -5 dBi (400 MHz, 413 MHZ) FoV gain > -6 dBi (390 MHz)	NC	Based on single antenna performance at ϕ = 90°.
Cross-Polarization Discrimination	-15 dB FoV	FoV XPOL < -6 dBi	---------	FoV XPOL < -4 dBi	NC	
Return Loss	1.4:1 (-15.56 dB)	2.06:1(-9.17 dB)	2.34:1(-7.92 dB)	2.37:1(-8.22 dB)	NC	
Weight (gr)	4000 g	---------	---------	6319 g	NC	

PARAMETER	SPEC. VALUE	WORST VALUE			STAT. OF COMP.	REMARKS
		INITIAL	POST VIBRATION	FINAL		
Power handling	55 W divided by 4 antennas (13.75 W)				C	Corona test successful (up to 100 W free of corona discharge)

Table 7-1: Compliance of Test Results.

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Conclusions to test results

The vibration test has been successfully fulfilled.

-Variation in post-vibration RL and isolation (changes in the contact points)

Thermal test, RF parameters suffered variation.

-Agreed with ESA: additional thermal cycles showed stability

Corona breakdown test.

-Results correlated with the analysis

RF tests: results similar to analysis.

-Some deviation observed at low frequencies

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Conclusions

In the frame of MAPP program, Breadboard and EM Antenna have been designed, manufactured, and tested, following the specific SOW

The EM has successfully evaluated the antenna concept.

- Dual circular polarization,
- Beam pointing
- Power handling (also under reentry scenarios)
- Miniaturization of the radiating element

Main challenges:

- Trade-off between mass, size and performance
- Non-broadside pointing requirements.

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Lessons learned and way forward

1) The number of radiating elements on a conformal array shall be preliminary well studied given the geometry of the vehicle.

- Conformal array of sub-arrays with tilted diagrams
- Conformal array of individual antennas
- Single sub-array at one side of the antenna

2) Future developments shall be specified by mission, reducing the complexity and mass of a general-purpose antenna.

- Bandwidth - Gain pattern - Coverage
- Polarization - Power

3) The RF design shall thus continue based on the already evaluated technology.

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ÁGORA Configuration Management